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SEG

Special Report

Geophysical Activity in 1984

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Geophysical Activity Committee

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Special Report
Geophysical Activity in 1984

SEG

Gerald E. Montgomery*

Report of the SEG Geophysical Activity Committee. Members of the Committee are Gerald E. Montgomery, Chairman, and Susan J. Allen, Lionel G. Cane, Charles E. Curtis, Kevin L. Debasitis, Harry R. Espey, Lin Evans, Ronald R. Hartman, Richard Hopkins, William C. Kellogg, Fritz P. Kronberger, H. Roice Nelson, Jr., Russell J. Senti, Paul L. Stoffa, Tommy A. Tillery, A. H. (Tony) Watts, M. D. (Don) Watts, and Data Analyst John T. Doherty.

Introduction

This report presents statistical data on worldwide geophysical activity in 1984. The data were gathered from survey questionnaires that were mailed to more than 500 companies, contractors, government agencies, and institutions throughout the free world. We have attempted to gather data from all users of geophysical techniques in the areas of petroleum, mining, geothermal, and groundwater exploration and from those who employ geophysical methods in engineering, oceanography, and research. Although response to the survey was good, we observed a 14 percent decrease in the number of questionnaires returned this year as compared to 1983.

Detailed information was gathered on airborne, drill hole, land, and marine geophysical surveys. Statistics were compiled on miles of coverage, number of stations, drill hole footage, time spent in crew-months or man-months, and acquisition costs. Data not supplied on the questionnaires by the respondent were estimated on the basis of massive statistical averaging for the area and techniques reported. This process is necessary to avoid distortion of individual statistical items.

This report, when compared to past annual reports, provides a basis for detecting and analyzing trends in technological developments and exploratory trends in geographical areas. Changes in these trends reflect the influence of factors, such as technological advances, inflation, government regulations, and exploration philosophy. Cost figures are also sensitive to many factors, such as operational environment, length and nature of the survey, type of instrumentation, etc. Unit costs reported by universities are substantially lower than those reported by industry due to the use of student labor and donated equipment. These costs, however, must be averaged with industry costs to accommodate the format of the report. Therefore, when examining unit cost figures, one must be cognizant of the broad spectrum of activity embraced by individual categories.

In response to monitoring new technological advances the annual questionnaire forms mailed this year contained revisions to include geophysical methods not reported separately in past years. The new methods itemized for reporting this year are vertical seismic profiles (VSP) and 3-D seismic surveys. Activity information was also requested on seismic surveys performed in transition zones, the areas between normal marine and land surveys.

Table 1. Total worldwide expenditures in US$ (thousands) by survey type and objective.

Type	Petroleum[1]	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
Land	2,038,154	20,275	5,562	1,584	660		8,125	2,074,360
Marine	1,347,701	1,570	10,078		10	6,667	2,363	1,368,389
Airborne	33,003	21,959				2,089	2,792	59,843
Drill Hole	1,688	358	648		137	3	131	2,965
Total	3,420,546	44,162	16,288	1,584	807	8,759	13,411	3,505,557

[1]Includes processing and interpretation costs for land and marine. See text for details.

Note: All tables in this report where figures are expressed in thousands of dollars have been rounded off as individual items; but the computer keeps track of all the truncated numbers and then the sums of the individual items are rounded off. As a result of this procedure, the rounded individual items may not add up precisely to the rounded sums.

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1984 Highlights

Worldwide expenditures on geophysical exploration in 1984 were down only 2.5 percent from last year (see Table 1). The decrease is reflected by the petroleum costs which were down 2 percent from 1983 and make up 97 percent of total expenditures on geophysical exploration. Other objective areas showed greater influence on the total decrease of 2.5 percent. Mining, engineering, geothermal, and groundwater showed decreases of 9, 41, 80, and 48 percent, respectively, while oceanography increased 47 percent and research expenditures were up 50 percent. Although there was a decrease in expenditures for land exploration in 1984 compared to 1983 for petroleum and minerals, expenditures for marine petroleum surveys were up.

Distribution of expenditures by geographic area and survey objective is shown in Table 2. Over 50 percent of all expenditures for geophysical work was spent in the United States. All area totals showed a decrease in expenditures over 1983 except Mexico, Europe, and Australia/New Zealand, which increased 156, 3, and 40 percent, respectively. The area with the largest decrease was South America with 22 percent. Under-reporting and a decrease in activity in Argentina, Brazil, and Venezuela could account for this decrease. The United States, Far East, Canada, Middle East, and Africa declined 19, 18, 17, and 4 percent, respectively.

The cost of processing and interpretation are included in Figures 1 and 2 and the petroleum column of Tables 1 and 2. All other tables show acquisition costs only. This year participants were not asked to report on processing and interpretation costs because less than 10 percent of the companies and contractors have responded in the past. Without that small amount of data, we used our own best estimate to arrive at the following figures: U.S. $765 per line-mile was used for the Western Hemisphere and U.S. $650 per line-mile was used for the Eastern Hemisphere. The higher cost in the Western Hemisphere is based

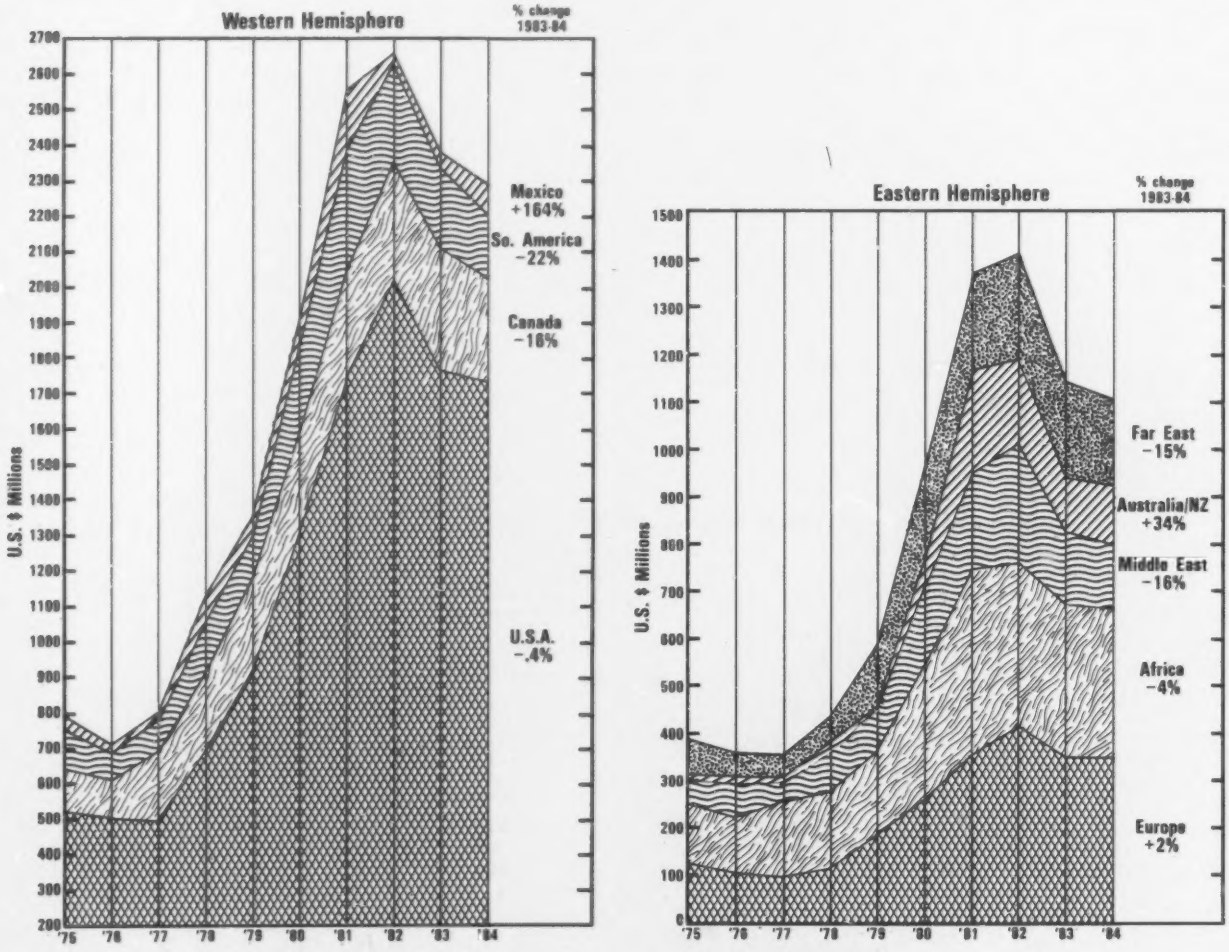

FIG. 1 Total expenditures on petroleum exploration, 1975-1984.

Table 2. Total worldwide expenditures in US$ (thousands) by area and survey objective.

Area	Petroleum[1]	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
International	26,175					4,595	1,323	32,093
U.S.A.	1,730,016	3,716	5,269	688	343	845	5,135	1,746,012
Canada	291,415	13,226	173		115	123	522	305,574
Mexico	89,060	162	1,500		30			90,752
South America	182,598	811				78	5	183,492
Europe	349,598	6,626	7,291	595	100	1,893	2,372	368,475
Africa	310,527	9,692	1,535	301	59	1,125	49	323,288
Middle East	131,716	1,034	292				343	133,385
Far East	181,257	3,045	108			100		184,510
Australia/ New Zealand	128,184	5,850	120		160		3,662	137,976
Total	3,420,546	44,162	16,288	1,584	807	8,759	13,411	3,505,557

[1] Includes processing and interpretation costs. See text for details.

on the premise that, in general, a more rigorous processing and interpretation treatment is required because of the subtle structural and stratigraphic prospects that may be economically viable objectives in much of the Western Hemisphere but are not usually primary targets in much of the Eastern Hemisphere. In the future as Eastern Hemisphere density of exploration increases in the basins of petroleum basins of the Eastern Hemisphere, we expect these costs per line-mile for processing and interpretation to equalize.

Petroleum exploration

Over 97 percent of all geophysical dollars were spent on petroleum exploration (U.S. $3.4 billion) in 1984. Expenditures in the U.S., Canada, and South America declined 4, 16, and 22 percent respectively, while Mexico showed a strong increase of 164 percent. Geophysical activity in the Western Hemisphere and Eastern Hemisphere showed similar declines of 2.4 percent.

A ten-year history of geophysical activity in both the Western and Eastern Hemisphere is shown in Figure 1.

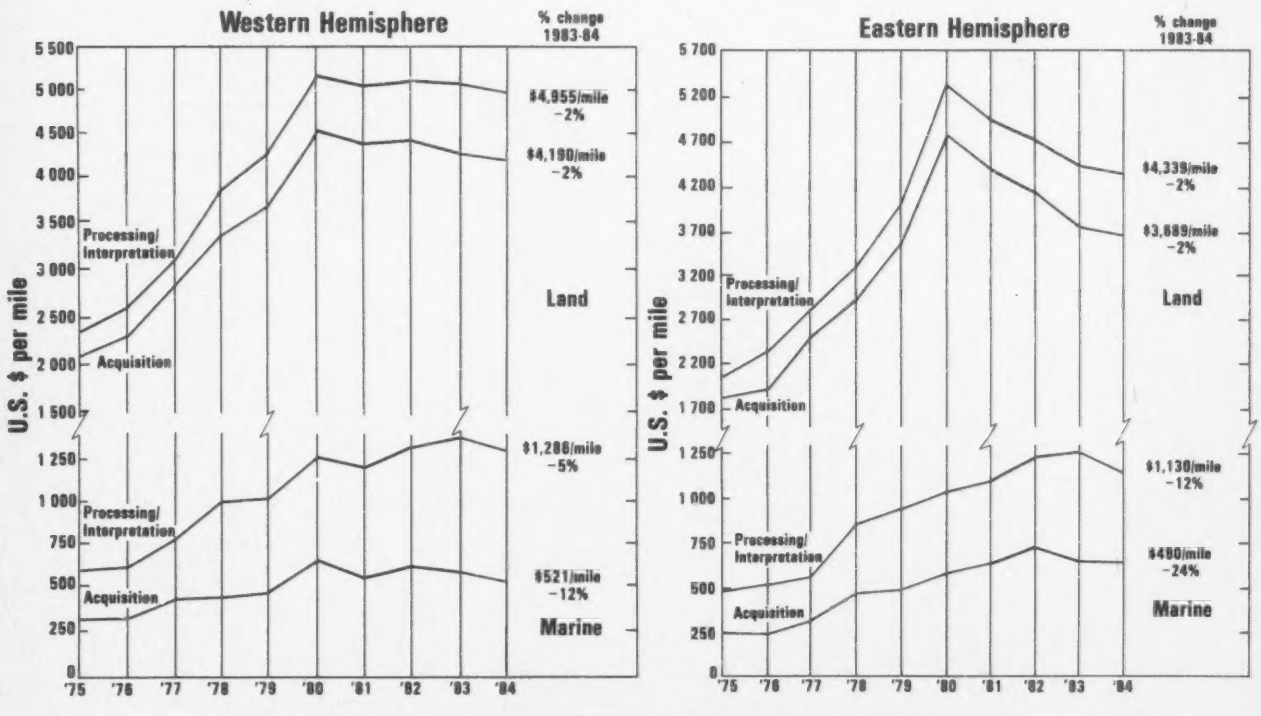

FIG. 2 Average cost per mile for petroleum surveys, 1975-1984.

Table 3. Worldwide petroleum land seismic activity.

Area	Acquisition costs - US$	Line-miles	Crew-months*		Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
			Company	Contract				
U.S.A.	856,511,585	185,888	671.8	3,461.9	4,133.8	44	207,196	4,607
Canada	176,138,925	52,492	52.5	522.4	574.9	91	306,365	3,355
Mexico	21,529.000	6,677		168.0	168.0	39	128,148	3,224
South America	89,771,948	27,982		390.7	390.7	71	229,772	3,208
Europe	127,576,008	25,727		578.1	578.1	44	220,681	4,958
Africa	184,650,830	45,926	9.0	570.0	579.0	79	318,913	4,020
Middle East	92,943,817	32,432		336.1	336.1	96	276,536	2,865
Far East	85,878,332	25,549		396.0	396.0	64	216,864	3,361
Australia/ New Zealand	72,271,851	23,082		209.3	209.3	110	345,220	3,131
Total	1,707,272,296	425,758	733.3	6,632.6	7,366.0	57	231,777	4,009

*Total includes government and university activity.

Table 4. Worldwide petroleum land seismic line-miles by energy source.

Area	Dynamite	Compressed air	Gas exploder	Weight drop	Solid chemical	Vibrator	Other	Total line-miles
U.S.A.	74,873	15,372	63	795	73	94,462	250	185,888
Canada	34,846	3,200		3,139		11,307		52,492
Mexico	4,585					2,091		6,677
South America	15,429	1,405			640	10,508		27,982
Europe	10,558	2,779		840		11,550		25,727
Africa	14,584	2,237		3,026		26,077		45,926
Middle East	5,848	186		6,474		16,772	3,150	32,432
Far East	21,960	1,700				1,889		25,549
Australia/ New Zealand	7,258			534	600	14,690		23,082
Total	189,941	26,879	63	14,808	1,313	189,346	3,400	425,758

Table 5. Worldwide petroleum marine seismic activity.

Area	Acquisition costs - US$	Line-miles	Crew-months*		Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
			Company	Contract				
International	19,176,635	25,096		31.9	31.9	786	600,771	764
U.S.A.	285,431,600	538,465	64.6	456.3	520.9	1,033	547,958	530
Canada	29,533,203	53,821		41.5	41.5	1.296	711,643	548
Mexico	26,601,000	43,826		65.5	65.5	669	406,122	606
South America	22,552,216	63,067	1.6	51.9	53.6	1,175	420,436	357
Europe	90,412,166	172,182	25.9	166.3	192.3	895	470,137	525
Africa	31,753,760	78,440	3.0	76.3	79.3	988	399,971	404
Middle East	6,347,600	14,519		15.3	15.3	944	412,717	437
Far East	32,360,287	71,311		76.3	76.3	934	424,119	453
Australia/ New Zealand	17,692,000	35,257		21.7	21.7	1,624	815,299	501
Total	561,860,467	1,095,989	95.2	1,003.3	1,098.5	997	511,461	512

*Total includes government and university activity.

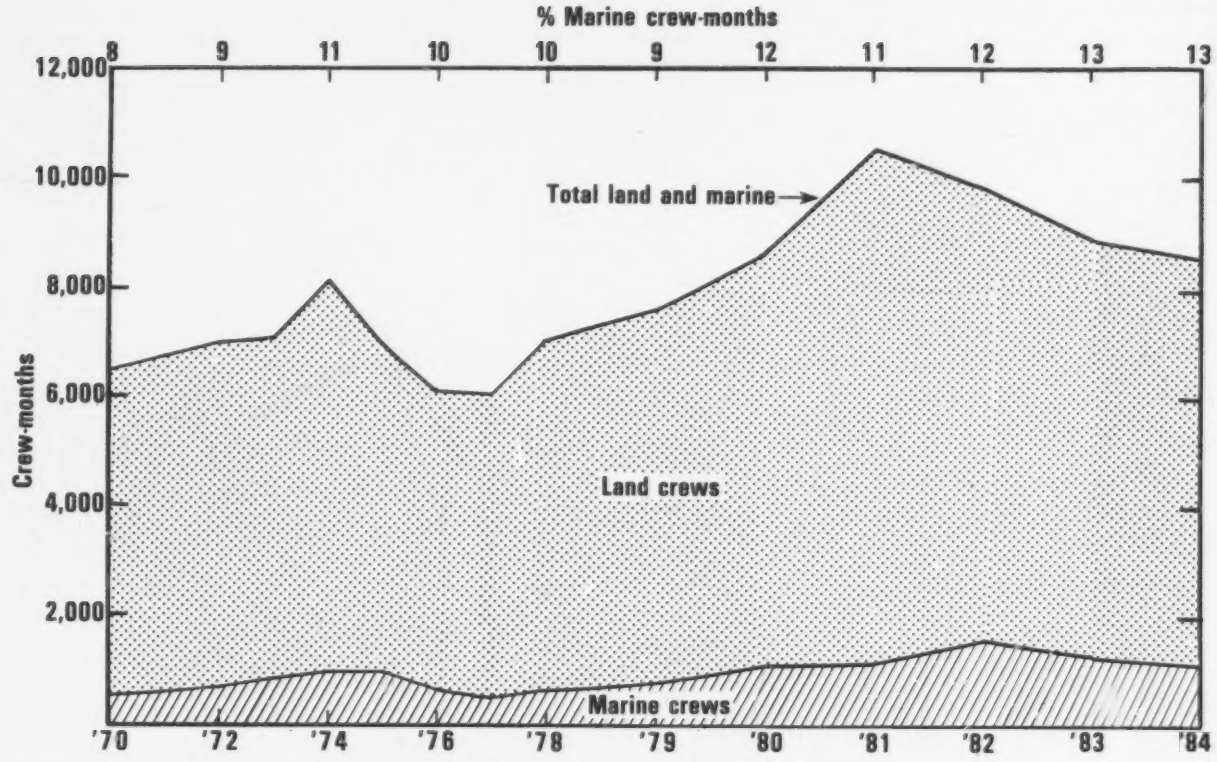

FIG. 3 Worldwide seismic activity in crew-months, 1970-1984.

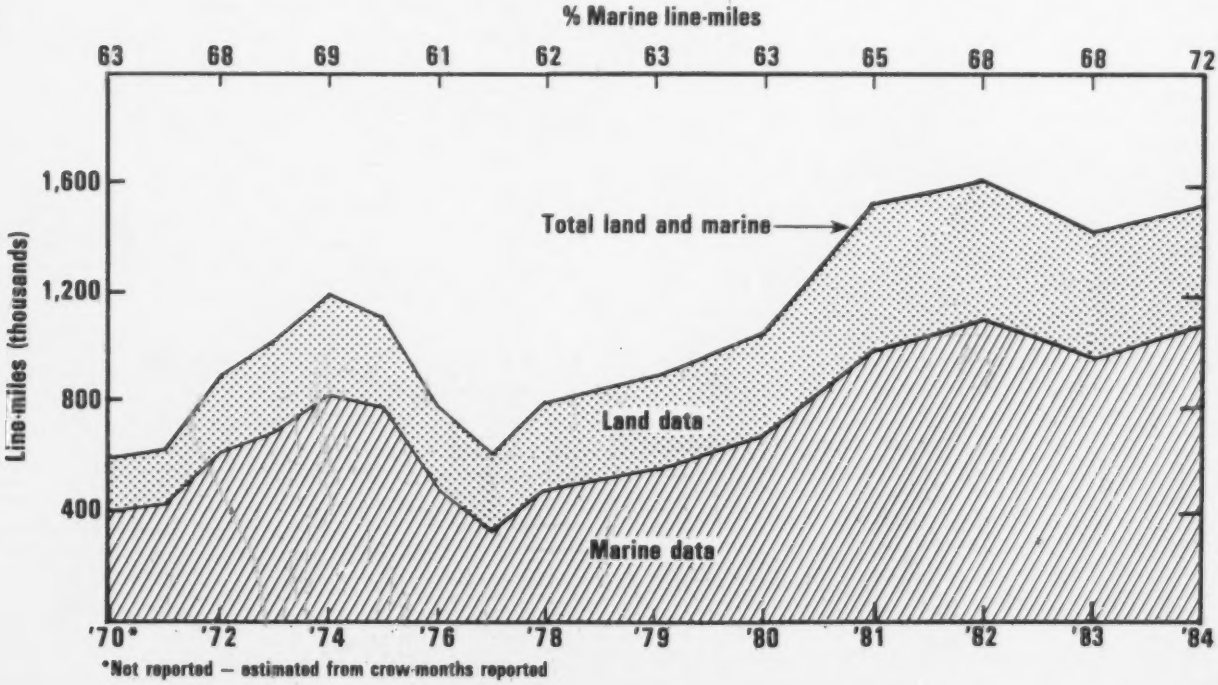

FIG. 4 Worldwide seismic activity in line-miles, 1970-1984.

Table 6. Worldwide petroleum marine seismic line-miles by energy source.

Area	Compressed air	Gas exploder	Implosive	Total line-miles
International	22,018		3,078	25,096
U.S.A.	535,465	3,000		538,465
Canada	53,821			53,821
Mexico	43,826			43,826
South America	55,152		7,915	63,067
Europe	162,892		9,290	172,182
Africa	74,508		3,932	78,440
Middle East	12,223		2,296	14,519
Far East	71,311			71,311
Australia/ New Zealand	35,257			35,257
Total	1,066,476	3,000	26,512	1,095,989

Seismic surveys

The seismic method accounted for 91 percent of all expenditures in geophysical activity. This statistic, plus the strong tendency for wildcatting to follow and parallel seismic activity, has caused those interested in forecasts of petroleum exploration to regard seismic activity as a barometer for exploration. A 10-year history of the cost of petroleum seismic surveys in both the Eastern and Western Hemispheres is shown in Figure 2. In the Western Hemisphere, the acquisition cost per mile of land seismic surveys dropped 2.0 percent, while marine costs declined 12 percent. In the Eastern Hemisphere, acquisition costs per mile for land seismic decreased 2 percent, while marine costs fell over 24 percent.

The total number of miles of seismic data recorded worldwide was down 5 percent on land and up over 13 percent in marine work (see Tables 3 and 5). We had an increase in the total number of miles of seismic worldwide, while cost per mile showed a decrease in both land and marine seismic surveys.

Both dynamite and Vibroseis® shared the number one position as the most popular land seismic energy source. Together these two energy sources account for 90 percent of all seismic land work. In marine work the air gun (compressed air) source accounted for 97.3 percent of the total line-miles (see Table 6).

A more comprehensive breakdown of statistical data on petroleum surveys, sorted by geographic area, can be seen in Table 7. Table 8 shows petroleum seismic activity by states in the U.S. Some of the states showing large gains over last year were Alabama, Arkansas, Colorado, Georgia, Iowa, Kansas, Michigan, North Dakota, and Oregon. The states of Alaska, California, Florida, and Oklahoma showed a significant reduction in activity in 1984. Tables 9 and 10 show petroleum seismic activity in Canada and Mexico, respectively.

A 52-year history of seismic exploration in the U.S. is shown in Figure 5. This information is compiled by the SEG Business Office. Data for this graph are gathered monthly by telephone.

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Gravity and magnetic surveys

Table 11 shows worldwide expenditures for gravity and magnetic surveys. The 1984 data show an 11 percent decrease in the use of these tools compared to last year. The petroleum objective contributed to most of this decrease with a 15 percent drop in activity, most of which was in Africa and the U.S.

Airborne surveys

Statistical data on airborne surveys are shown in Tables 12, 13A, and 13B. Expenditures for worldwide airborne survey increased over 15 percent from 1983. Africa had a 36 percent increase in airborne expenditures for mineral exploration. Magnetic surveys continued to be the most popular, however, radiometric gamma ray was a significant second.

Land mining

Tables 14A and 14B report expenditures and methods utilized for land mining in the Western and Eastern Hemispheres. Reported usage of geophysical exploration for minerals using land methods was up from 1983 for the Eastern Hemisphere and down for the Western Hemisphere. The largest decrease was for Canada.

Engineering, geothermal, groundwater, oceanography, and research

Table 15 reports engineering/groundwater activity. Table 16 contains worldwide geothermal work. Average unit costs for all survey objectives, types, and methods can be found in Table 17. Expenditures for groundwater and engineering activity is down 41 percent (Table 15). Geothermal activity is down in all areas with a decrease in expenditures of 80 percent. Research for land and airborne are up with the most significant increase being in Australia/New Zealand, Europe, and the U.S.A. Oceanography expenditures increased slightly in marine work, and an 1800 percent increase in airborne work. This could be a result of nonreporting in 1983 or the indication of a new trend in oceanography

(Text continued on p. 54)

Table 7. Worldwide average unit costs for petroleum surveys.

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
International						
Marine						
Seismic (*P*-wave)						
Compressed air	24.0	19,806	16,423,635	825	684,318	829
Implosive	4.9	3,078	1,178,000	625	239,430	382
Seismic (*S*-wave)						
Compressed air	3.0	2,212	1,575,000	737	525,000	711
Electrical field	.4	470	250,000	1,175	625,000	531
Airborne						
Gravity	14.5	[400,000]	6,700,000	[27,586]	462,068	[16]
Radiometric						
Gamma ray	.2	1,266	31,650	5,064	126,600	25
U.S.A.						
Land						
Seismic (*P*-wave)						
Dynamite	1,979.1	69,963	458,438,226	35	231,631	6,552
Compressed air	102.0	15,372	23,939,182	150	234,697	1,557
Gas exploder	1.0	63	271,264	63	271,264	4,305
Weight drop	18.6	795	2,549,734	42	137,082	3,207
Solid chemical	2.0	73	490,000	36	245,000	6,712
Vibratory	1,688.3	81,266	281,216,282	48	166,563	3,460
Other	9.0	250	3,900,000	27	433,333	15,600
Seismic (*S*-wave)						
Dynamite	84.0	4,752	23,457,400	56	279,088	4,936
Vibratory	240.6	13,195	61,470,915	54	255,426	4,658
Seismic (refraction)						
Dynamite	9.0	158	778,582	17	86,509	4,927
Gravity	22.0	6,261	453,400	284	20,609	72
Gravity	39.7	[34,739]	660,100	[873]	16,606	[19]
Magnetic	1.0	480	40,000	480	40,000	83
Magnetic	1.0	[632]	7,000	[632]	7,000	[11]
Electromagnetic						
Time domain	2.2	[410]	180,000	[186]	81,818	[439]
Induced polarization	2.0	12	97,000	6	48,500	8,083
Magnetotelluric	31.5	[1,807]	4,210,624	[57]	133,670	[2,330]
Magnetotelluric	(2.0)	[45]	140,445	[22]	(70,222)	[3,121]
Other	2.0	10	467,446	5	233,723	42,884
Other	(1.0)	20	12,000	(20)	(12,000)	600
Marine						
Seismic (*P*-wave) Compressed air	500.8	529,750	272,363,600	1,057	543,857	514
Seismic (*P*-wave) Gas exploder	11.0	3,000	6,300,000	272	572,727	2,100
Seismic (*S*-wave) Compressed air	6.3	3,650	5,298,000	579	840,952	1,451
Seismic (refraction)						
Compressed air	2.8	2,064	1,470,000	737	525,000	711
Airborne						
Magnetic	94.2	225,807	5,075,691	2,397	53,882	22
Magnetic	(1.2)	7,301	260,400	(6,084)	(217,000)	35
VLF	1.5	30,000	1,660,000	20,000	1,106,666	55
Radiometric						
Gamma ray	23.0	176,570	2,472,000	7,676	107,478	14
Drill hole						
Resistivity	(.1)	(2,100)	600	(21,000)	(6,000)	(1)

*Total includes government and university activity.

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Canada						
Land						
Seismic (*P*-wave)						
Dynamite	362.7	34,612	124,500,623	95	343,232	3,596
Compressed air	32.0	3,200	7,600,000	100	237,500	2,375
Weight drop	37.3	3,139	14,254,290	84	382,152	4,541
Vibratory	123.4	10,357	26,121,012	83	211,677	2,522
Seismic (*S*-wave)						
Vibratory	17.5	950	3,550,000	54	202,857	3,734
Seismic (refraction)						
Dynamite	2.0	233	113,000	116	56,500	484
Magnetic	3.0	822	60,000	274	20,000	72
Resistivity	1.0	30	14,000	30	14,000	466
Self-potential	1.0	75	17,500	75	17,500	233
Magnetotelluric	5.0	[238]	698,000	[47]	139,600	[2,932]
Marine						
Seismic (*P*-wave)						
Compressed air	30.8	32,526	10,289,203	1,056	334,065	316
Seismic (*S*-wave)						
Compressed air	6.7	14,100	15,024,000	2,104	2,242,388	1,065
Seismic (refraction)						
Compressed air	4.0	7,195	4,220,000	1,798	1,055,000	586
Airborne						
Magnetic	9.3	87,170	1,547,869	9,322	165,547	17
Mexico						
Land						
Seismic (*P*-wave)						
Dynamite	36.0	1,800	345,000	50	9,583	191
Vibratory	24.0	600	760,000	25	31,666	1,266
Seismic (*S*-wave)						
Dynamite	84.0	2,785	18,984,000	33	226,000	6,814
Vibratory	24.0	1,491	1,440,000	62	60,000	965
Gravity	96.0	9,400	1,000,000	97	10,416	106
Resistivity	6.0	[210]	45,000	[35]	7,500	[214]
Magnetotelluric	24.0	[190]	750,000	[7]	31,250	[3,947]
Marine						
Seismic (*S*-wave)						
Compressed air	26.0	19.178	13,650,000	737	525,000	711
Seismic (refraction)						
Compressed air	39.5	24,648	12,951,000	624	327,873	525
South America						
Land						
Seismic (*P*-wave)						
Dynamite	211.4	15,429	49,491,450	72	234,112	3,207
Compressed air	9.3	1,405	3,020,678	151	324,804	2,149
Solid chemical	5.0	640	1,500,000	128	300,000	2,343
Vibratory	150.0	9,539	32,329,820	63	215,532	3,389
Seismic (*S*-wave)						
Vibratory	15.0	969	3,430,000	64	228,666	3,538
Gravity	1.0	[650]	29,250	[650]	29,250	[45]
Gravity	(8.0)	[651]	24,087	[81]	(3,010)	[37]

*Total includes government and university activity.

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
South America (cont.)						
Marine						
Seismic (*P*-wave)						
Compressed air	37.7	52,792	17,706,216	1,397	468,666	335
Implosive	12.6	7,915	3,166,000	625	250,078	400
Seismic (*S*-wave)						
Compressed air	2.2	1,622	1,155,000	737	525,000	711
Seismic (refraction)						
Compressed air	1.0	737	525,000	737	525,000	711
Gravity	1.0	[284]	79,000	[284]	79,000	[278]
Airborne						
Magnetic	2.8	14,770	490,000	5,275	175,000	33
Europe						
Land						
Seismic (*P*-wave)						
Dynamite	301.2	9,421	71,522,153	31	237,457	7,591
Seismic (*P*-wave)						
Compressed air	18.5	2,779	5,384,476	150	291,052	1,937
Weight drop	26.8	840	2,512,257	31	93,740	2,990
Vibratory	218.5	11,550	46,077,122	52	210,879	3,989
Seismic (*S*-wave)						
Dynamite	12.1	1,127	1,630,000	93	134,710	1,445
Seismic (refraction)						
Dynamite	1.0	10	450,000	10	450,000	45,000
Gravity	5.5	1,471	156,756	267	28,501	106
Resistivity	8.0	120	120,000	15	15,000	1,000
Self-potential	1.0	75	17,500	75	17,500	233
Induced polarization	3.0	36	125,118	12	41,706	3,475
Marine						
Seismic (*P*-wave)						
Compressed air	128.7	126,972	61,549,166	986	478,051	484
Implosive	14.8	9,290	3,296,000	625	221,803	354
Seismic (*S*-wave)						
Compressed air	29.4	21,685	15,435,000	737	525,000	711
Seismic (refraction)						
Compressed air	19.3	14,235	10,132,000	737	524,974	711
Gravity	1.2	2,919	111,197	2,432	92,664	38
Airborne						
Radiometric						
Gamma ray	3.0	14,403	360,075	4,801	120,025	25
Drill hole						
Sonic/velocity logging	(11.3)	(169,444)	338,887	(14,995)	(29,990)	(1)
Africa						
Land						
Seismic (*P*-wave)						
Dynamite	190.1	12,721	65,967,329	66	347,013	5,185
Compressed air	12.5	1,380	3,644,986	110	291,598	2,641
Weight drop	34.0	3,026	14,911,000	89	438,558	4,927
Vibratory	287.8	23,710	92,767,515	82	322,333	3,912
Seismic (*S*-wave)						
Dynamite	15.5	1,444	2,090,000	93	134,838	1,446
Compressed air	9.2	857	1,240,000	93	134,782	1,446
Vibratory	25.4	2,367	3,430,000	93	135,039	1,448

*Total includes government and university activity.

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

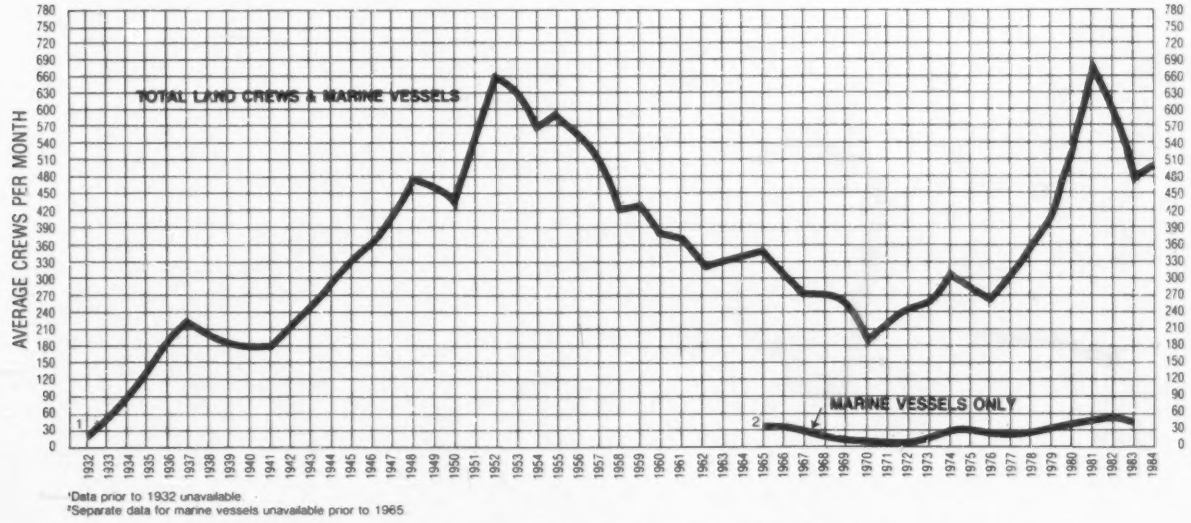
Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Africa, Land (cont.)						
Seismic (refraction)						
Dynamite	4.5	419	600,000	93	133,333	1,430
Gravity	4.0	1,000	120,000	250	30,000	120
Gravity	14.0	[15,776]	490,000	[1,126]	35,000	[31]
Gravity	(6.0)	[360]	14,400	[60]	(2,400)	[40]
Resistivity	.5	7	7,500	15	15,000	1,000
Marine						
Seismic (*P*-wave)						
Compressed air	60.0	64,848	23,396,000	1,080	389,933	360
Implosive	6.2	3,932	1,482,760	625	235,732	377
Seismic (*S*-wave)						
Compressed air	10.7	7,889	5,615,000	737	524,766	711
Seismic (refraction)						
Compressed air	2.4	1,770	1,260,000	737	525,000	711
Airborne						
Gravity	4.0	[95,000]	3,250,000	[23,750]	812,500	[34]
Magnetic	12.5	340,558	7,593,000	27,244	607,440	22
Magnetic	(28.0)	66,108	1,520,484	(2,361)	(54,303)	23
Radiometric						
Gamma ray	2.4	11,591	289,775	4,789	119,741	25
Middle East						
Land						
Seismic (*P*-wave)						
Dynamite	51.1	3,798	17,789,171	74	348,124	4,683
Weight drop	36.0	6,474	17,051,657	179	473,657	2,633
Vibratory	127.1	10,798	41,652,989	84	327,718	3,857
Seismic (*S*-wave)						
Dynamite	22.0	2,050	2,970,000	93	135,000	1,448
Compressed air	2.0	186	270,000	93	135,000	1,448
Vibratory	64.1	5,974	8,650,000	93	134,945	1,447
Other	33.8	3,150	4,560,000	93	134,911	1,447
Gravity	12.0	[7,448]	230,000	[620]	19,166	[30]
Marine						
Seismic (*P*-wave)						
Compressed air	5.0	7,283	2,185,000	1,456	437,000	300
Implosive	3.6	2,296	918,600	624	249,619	400
Seismic (*S*-wave)						
Compressed air	1.0	737	525,000	737	525,000	711
Seismic (refraction)						
Compressed air	5.7	4,202	2,719,000	737	477,017	646
Airborne						
Magnetic	10.3	69,735	1,662,000	6,770	161,359	23
Drill hole						
Sonic/velocity logging	(.5)	(7,498)	14,995	(14,996)	(29,990)	(1)
Far East						
Land						
Seismic (*P*-wave)						
Dynamite	294.6	16,989	59,120,292	57	200,679	3,479
Seismic (*P*-wave)						
Compressed air	11.0	1,700	5,225,000	154	475,000	3,073
Vibratory	10.4	1,889	2,513,040	181	241,638	1,330

*Total includes government and university activity.

Table 7. Worldwide average unit costs for petroleum surveys (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Far East, Land (cont.)						
Seismic (*S*-wave)						
Dynamite	80.0	4,971	19,020,000	62	237,750	3,826
Gravity	2.0	500	60,000	250	30,000	120
Marine						
Seismic (*P*-wave)						
Compressed air	44.6	41,668	15,940,287	934	357,405	382
Seismic (*S*-wave)						
Compressed air	31.7	29,643	16,420,000	935	517,981	553
Australia/New Zealand						
Land						
Seismic (*P*-wave)						
Dynamite	71.0	7,258	24,287,128	102	342,072	3,346
Weight drop	6.0	534	1,557,000	89	259,500	2,915
Solid chemical	6.0	600	2,400,000	100	400,000	4,000
Vibratory	95.3	10,039	32,487,723	105	340,720	3,236
Seismic (*S*-wave)						
Vibratory	31.0	4,651	11,540,000	150	372,258	2,481
Gravity	5.0	[9,400]	160,000	[1,880]	32,000	[17]
Marine						
Seismic (*P*-wave)						
Compressed air	11.0	20,094	6,028,000	1,826	548,000	299
Seismic (*S*-wave)						
Compressed air	9.1	11,406	8,444,000	1,253	927,912	740
Seismic (refraction)						
Compressed air	1.6	3,757	3,220,000	2,348	2,012,300	857
Airborne						
Magnetic	.4	2,295	90,309	5,737	225,772	39

*Total includes government and university activity.



¹Data prior to 1932 unavailable.
²Separate data for marine vessels unavailable prior to 1965.

FIG. 5 History of seismic exploration activity in the U.S., 1932-1984. (The total crews working in a given year is not synonymous with the crew-months worked that year.)

Table 8. U.S.A. petroleum seismic activity by area.

State	Acquisition costs - US$	Line-miles	Crew-months*		Total months*
			Company	Contract	
Land					
Undesignated	50,023,150	10,741	.0	226.3	226.3
Alaska	41,349,000	3,960	.0	78.5	78.5
Alabama	31,930,514	7,433	39.0	125.5	164.5
Arkansas	10,486,716	1,668	17.0	22.5	39.5
Arizona	1,510,750	249	4.7	2.5	7.2
California	23,939,174	5,764	34.0	118.2	152.2
Colorado	29,807,786	9,014	8.0	200.4	208.4
Florida	1,647,606	315	2.1	7.5	9.6
Georgia	1,831,000	993	.0	15.0	15.0
Iowa	4,091,370	1,092	5.0	10.7	15.7
Idaho	2,758,000	150	2.0	4.0	6.0
Illinois	1,875,485	710	.0	12.5	12.5
Indiana	1,481,949	605	.0	12.5	12.5
Kansas	15,985,132	5,291	25.6	93.3	119.0
Kentucky	349,000	148	.0	2.5	2.5
Louisiana	111,958,398	20,974	93.5	342.3	435.8
Massachusetts	145,000	109	1.0	.0	1.0
Maryland	210,000	27	.0	1.0	1.0
Maine	489,794	78	.0	2.5	2.5
Michigan	35,464,091	8,974	25.2	138.0	163.2
Minnesota	121,790	80	.0	1.5	1.5
Missouri	100,707	42	.0	.7	.7
Mississippi	20,561,038	3,100	31.9	53.5	85.4
Montana	23,282,490	5,323	9.5	115.5	125.0
North Dakota	13,285,945	3,580	10.0	64.4	74.4
Nebraska	3,108,219	1,016	.0	16.5	16.5
New Mexico	20,047,027	5,216	9.7	104.0	113.7
Nevada	10,257,330	1,675	15.5	38.7	54.2
New York	1,624,007	289	.0	12.0	12.0
Ohio	1,416,435	401	5.0	6.5	11.5
Oklahoma	39,633,024	9,926	27.1	204.3	231.4
Oregon	5,339,931	1,108	9.0	23.5	32.5
Pennsylvania	341,000	106	.0	2.6	2.6
South Dakota	576,555	196	.0	4.0	4.0
Tennessee	2,897,034	645	.0	19.4	19.4
Texas	226,095,696	56,780	223.3	975.9	1,199.2
Utah	41,982,593	4,259	31.7	89.5	121.3
Virginia	717,602	90	.0	3.2	3.2
Vermont	383,000	131	.0	3.0	3.0
Washington	5,571,526	279	11.0	5.5	16.5
Wisconsin	1,130,936	365	.0	8.5	8.5
West Virginia	2,013,552	733	.0	17.2	17.2
Wyoming	68,690,233	12,239	30.5	275.7	306.2
Total land	856,511,585	185,888	671.8	3,461.9	4,133.8
Marine					
Undesignated	45,000,000	107,520	.0	12.0	12.0
East Coast	8,667,720	15,101	2.9	13.0	15.9
Gulf Coast	177,559,380	323,429	57.0	321.2	378.2
Off Alaska	42,105,000	69,010	1.2	93.3	94.5
West Coast	12,099,500	23,404	3.5	16.8	20.3
Total Marine	285,431,600	538,465	64.6	456.3	520.9
Total U.S.A.	1,141,943,185	724,353	736.4	3,918.2	4,654.7

*Total includes government and university activity.

Table 9. Canada petroleum seismic activity by area.

Province	Acquisition costs - US$	Line-miles	Crew-months*		Total months*
			Company	Contract	
Land					
Undesignated	10,080,500	2,826	.0	44.4	44.4
Alberta	119,109,545	40,073	32.5	386.9	419.4
British Columbia	11,429,050	2,016	.0	26.0	26.0
Manitoba	6,348,218	222	.5	3.3	3.8
New Brunswick	1,630,800	234	6.0	.0	6.0
Northwest Territories	14,973,635	1,859	.0	22.4	22.4
Ontario	1,200,000	400	10.0	.0	10.0
Saskatchewan	11,457,177	4,860	3.5	39.2	42.7
Total Land	176,138,925	52,492	52.5	522.4	574.9
Marine					
Alberta	425,000	250	.0	3.0	3.0
East Coast	10,908,000	18,344	.0	8.5	8.5
Northwest Territories	9,864,203	32,276	.0	27.8	27.8
West Coast	8,336,000	2,951	.0	2.2	2.2
Total Marine	29,533,203	53,821	.0	41.5	41.5
Total Canada	205,672,128	106,314	52.5	563.9	616.4

*Total includes government and university activity.

Table 10. Petroleum seismic activity in Mexico.

Area	Acquisition costs - US$	Line-miles	Crew-months		Total months
			Company	Contract	
Land					
Various	21,529,000	6,677	.0	168.0	168.0
Marine					
Various	26,601,000	43,826	.0	65.5	65.5
Total Mexico	48,130,000	50,503	.0	233.5	233.5

Table 11. Total worldwide expenditures on gravity and magnetic surveys in US$ (thousands).

Area	Petroleum	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
International	6,700					1,550	664	8,914
U.S.A.	6,496	1,605	20	50	8	649	102	8,932
Canada	1,607	1,676	3		15		235	3,537
Mexico	1,000	62						1,062
South America	622	6						628
Europe	267	55		220				542
Africa	12,987	3,316					2	16,307
Middle East	1,892	267						2,159
Far East	60	981						1,041
Australia/ New Zealand	250	3,693					1,431	5,375
Total	31,884	11,663	23	270	24	2,199	2,435	48,500

Table 12. Total worldwide expenditures on airborne surveys in US$ (thousands).

Area	Petroleum	Minerals	Oceanography	Research	Total
International	6,731		1,440	273	8,445
U.S.A.	9.468	2.633	649	175	12,926
Canada	1,547	10,246		177	11,970
Mexico		62			62
South America	490	393			883
Europe	360	109		474	943
Africa	12,653	2,653			15,307
Middle East	1,662	767		343	2,772
Far East		974			974
Australia/ New Zealand	90	4,118		1,349	5,557
Total	33,003	21,959	2,089	2,792	59,844

Table 13A. Western Hemisphere airborne activity in US$ (thousands).

	International		USA		Canada		Mexico		South America	
Survey method	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Gravity	[439,000]	7,340								
Magnetic	148,125	1,073	383,009	7,423	155,131	2,941	11,250	62	14,770	490
Electromagnetic										
Time domain			200	60						
Combined EM/Mag.					35,000	3,500				
VLF			30,251	1,700						
Input			12,910	1,171	61,500	3,842			2,443	393
Radiometric										
Gamma ray	1,266	31	176,570	2,472	23,400	585				
Remote sensing										
Thermal infrared			3,030	100						
Other					26,373	1,102				
Total	149,391 [439,000]	8,445	605,970	12,926	301,404	11,970	11,250	62	17,213	883

[No. of stations]

Table 13B. Eastern Hemisphere airborne activity in US$ (thousands).

	Europe		Africa		Middle East		Far East		Australia/New Zealand	
Survey method	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Gravity			[95,000]	3,250						
Magnetic			471,899	11,190	69,735	1,662	98,393	974	405,931	4,718
Electromagnetic										
Time domain									12,139	839
Frequency domain					3,328	489				
Combined EM/Mag.	1,500	108								
Input			2,771	243						
Radiometric										
Gamma ray	14,451	361	70,028	623						
Remote sensing										
Thermal infrared					10,392	343				
Multispectral scanning					23,125	277				
Multispectral scanning	[76]	474								
Total	15,951 [76]	943	544,698 [95,000]	15,307	106,580	2,772	98,393	974	418,070	5,557

[No. of stations]

Table 14A. Western Hemisphere land mining activity in US$ (thousands).

Survey method	USA		Canada		Mexico		South America	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Seismic (P-wave)								
Dynamite			12	96				
Seismic (refraction)								
Dynamite	7	67	53	93				
Weight drop			3	14				
Other	7	15						
Gravity	287	94	409	244				
Gravity	[2,575]	39						
Magnetic	75	11	891	153			14	6
Magnetic	[2,400]	39						
Resistivity	57	67						
Electromagnetic								
Time domain	196	210	124	100			26	50
Frequency domain	61	35	424	226	1	1		
Combined EM/Mag.	101	58	1,166	296				
VLF	75	31	463	33				
VLF	[540]	1						
Induced polarization	100	92	1,509	1,535	173	99	44	85
Induced polarization	[150]	10						
Radiometric								
Gamma ray			513	24			120	80
Neutron activation	10	7						
Neutron activation	[150]	12						
Remote sensing								
Multispectral scanning	[405]	46						
Magnetotelluric	3	14						
Magnetotelluric	[40]	130					[60]	197
Other	75	12	200	56				
Total	1,054	995	5,767	2,874	174	100	204	418
[No. of stations]	[6,260]						[60]	

Table 14B. Eastern Hemisphere land mining activity in US$ (thousands).

Survey method	Europe		Africa		Middle East		Far East		Australia/New Zealand	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Seismic (P-wave)										
Dynamite	760	4,513	100	300			180	480		
Vibratory	55	1,011	1,372	4,959					18	73
Seismic (refraction)										
Dynamite							9	4		
Weight drop							6	2		
Gravity	150	40	909	1,118	100	267	26	1	434	364
Gravity			[1,400]	14					[2,500]	50
Magnetic	81	15	895	107			29	4		
Resistivity			550	21			7	7		
Electromagnetic										
Time domain	305	200	173	68					344	324
Time domain	[414]	522								
Frequency domain			150	34						
Combined EM/Mag.			315	170						
VLF	12	2	71	5						
Induced polarization	30	26	628	226					496	561
Radiometric										
Gamma ray			16	3						
Magnetotelluric	30	150								
Other	200	36							200	200
Total	1,623	6,516	5,179	7,029	100	267	257	500	1,492	1,572
[No. of stations]	[414]		[1,400]						[2,500]	

Table 15. Worldwide groundwater and engineering activity.

Survey method	Area			Time*		Cost
	Line-miles	Stations	Footage	Crew-months	Man-months	US$ (thousands)
Seismic (P-wave)						
Dynamite	67			3.0		695.3
Compressed air	2,454			11.0		3,890.0
Electrical	4,840			23.4		3,080.0
Gas exploder	1,740			9.3		2,065.0
Weight drop	73			7.8		245.6
Solid chemical	3			1.1		15.3
Vibratory	300			4.0		428.0
Passive monitoring		5		12.0		150.0
Other	36			5.0	4.0	111.2
Seismic (S-wave)						
Electrical	50			1.0		10.0
Seismic (refraction)						
Dynamite	217	210		22.1	23.6	1,507.9
Compressed air	5,405	1,000		8.9	10.0	1,315.0
Electrical	360			.6		52.5
Weight drop	3		8,000	2.6	1.8	41.7
Solid chemical				.5		18.0
Gravity	35			.5		8.5
Magnetic	174		500	1.5	.5	38.5
Resistivity	2,266	1,348	24,600	80.2	12.4	905.6
Self-potential			32,000		4.6	26.0
Sonic/velocity logging			67,000	4.0	5.3	115.0
Electromagnetic						
Time domain	101	24		3.1	2.0	108.5
Frequency domain	5			.5		3.0
VLF	5			.5		3.0
Radiometric						
Gamma ray			9,500		1.5	21.3
Remote sensing						
Thermal infrared					1.0	10.0
Microwave radiometry	3,000			28.0		1,500.0
Temperature gradient			2,300		2.3	11.5
Other	109		110,580	1.0	67.8	707.9
Total	21,247	2,589	254,480	232.0	136.9	17,098.7

*Total includes government and university activity.

Table 16. Worldwide geothermal activity.

Survey method	Area			Time*		Cost
	Line-miles	Stations		Crew-months	Man-months	US$ (thousands)
Seismic (P-wave)						
Dynamite	60			1.5		375.0
Seismic (refraction)						
Passive monitoring		240		24.0		200.0
Gravity	1,605	2,000		13.5		270.0
Resistivity	255			8.5		170.0
Electromagnetic						
Time domain		123		.7		55.0
Temperature gradient	1,312			1.0		131.2
Magnetotelluric		114		1.0	1.0	383.2
Total	3,232	2,477		50.2	1.0	1,584.4

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method.

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Petroleum						
Land						
Seismic (*P*-wave)						
Dynamite	3,497.3	171,992	871,461,372	49	249,181	5,066
Compressed air	185.3	25,836	48,814,322	139	263,434	1,889
Gas exploder	1.0	63	271,264	63	271,264	4,305
Weight drop	158.7	14,808	52,835,938	93	332,929	3,568
Solid chemical	13.0	1,313	4,390,000	101	337,692	3,343
Vibratory	2,724.8	159,748	555,925,503	58	204,017	3,480
Other	9.0	250	3,900,000	27	433,333	15,600
Seismic (*S*-wave)						
Dynamite	297.6	17,132	68,151,400	57	228,964	3,977
Compressed air	11.2	1,043	1,510,000	93	134,821	1,446
Vibratory	417.6	29,600	93,510,915	70	223,892	3,159
Other	33.8	3,150	4,560,000	93	134,911	1,447
Seismic (refraction)						
Dynamite	16.5	820	1,941,582	49	117,671	2,366
Gravity	129.5	18,632	1,790,156	143	13,823	96
Gravity	71.7	[68,013]	1,569,350	[947]	21,872	[23]
Gravity	(14.0)	[1,011]	38,487	[72]	(2,749)	[38]
Magnetic	4.0	1,302	100,000	325	25,000	76
Magnetic	1.0	[632]	7,000	[632]	7,000	[11]
Resistivity	9.5	157	141,500	16	14,894	898
Resistivity	6.0	[210]	45,000	[35]	7,500	[214]
Self-potential	2.0	150	35,000	75	17,500	233
Electromagnetic						
Time domain	2.2	[410]	180,000	[186]	81,818	[439]
Induced polarization	5.0	48	222,118	9	44,423	4,627
Magnetotelluric	60.5	[2,235]	5,658,624	[36]	93,530	[2,531]
Magnetotelluric	(2.0)	[45]	140,445	[22]	(70,222)	[3,121]
Other	2.0	10	467,446	5	233,723	42,884
Other	(1.0)	20	12,000	(20)	12,000)	600
Marine						
Seismic (*P*-wave)						
Compressed air	842.7	895,740	425,881,107	1,062	505,358	475
Gas exploder	11.0	3,000	6,300,000	272	572,727	2,100
Implosive	42.4	26,512	10,041,360	625	236,768	378
Seismic (*S*-wave)						
Compressed air	126.1	112,124	83,141,000	889	659,325	741
Seismic (refraction)						
Compressed air	76.3	58,611	36,497,000	768	478,335	622
Gravity	1.2	2,919	111,197	2,432	92,664	38
Gravity	1.0	[284]	79,000	[284]	79,000	[278]
Electrical field	.4	470	250,000	1,175	625,000	531
Airborne						
Gravity	18.5	[495,000]	9,950,000	[26,756]	537,837	[20]
Magnetic	129.5	740,335	16,458,869	5,714	127,046	22
Magnetic	(29.2)	73,409	1,780,884	(2,514)	(60,989)	24
VLF	1.5	30,000	1,660,000	20,000	1,106,666	55
Radiometric						
Gamma ray	28.6	203,830	3,153,500	7,109	109,993	15
Drill Hole						
Resistivity	(.1)	(2,100)	600	(21,000)	(6,000)	(1)
Sonic/velocity logging	(11.8)	(176,942)	353,882	(14,995)	(29,990)	(1)

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Minerals						
Land						
Seismic (*P*-wave)						
Dynamite	30.3	1,052	5,389,892	34	177,884	5,123
Vibratory	31.6	1,445	6,043,442	45	190,946	4,182
Seismic (refraction)						
Dynamite	5.5	70	165,730	12	30,132	2,354
Weight drop	.8	9	16,900	11	21,125	1,877
Other	1.0	7	15,000	7	15,000	2,142
Gravity	66.6	2,170	2,122,145	32	31,844	977
Gravity	6.5	[6,475]	103,500	[996]	15,923	[15]
Gravity	(3.0)	146	7,600	(48)	(2,533)	52
Magnetic	25.5	1,107	245,027	43	9,578	221
Magnetic	3.7	[2,400]	38,300	[640]	10,213	[15]
Magnetic	(19.6)	879	52,650	(44)	(2,686)	59
Resistivity	14.0	566	89,885	40	6,379	158
Resistivity	(7.5)	50	6,600	(6)	(880)	132
Electromagnetic						
Time domain	47.1	1,113	943,544	23	19,998	847
Time domain	(3.0)	55	10,600	(18)	(3,533)	192
Time domain	(5.0)	[414]	522,542	[82]	(104,508)	[1,262]
Frequency domain	15.6	546	275,792	34	17,600	504
Frequency domain	(10.0)	90	22,000	(9)	(2,200)	244
Combined EM/Mag.	36.9	1,488	509,471	40	13,784	342
Combined EM/Mag.	(4.5)	95	16,500	(21)	(3,666)	173
VLF	12.3	624	71,311	50	5,760	114
VLF	(1.0)	[540]	1,000	[540]	(1,000)	[1]
Induced polarization	152.0	2,525	2,528,391	16	16,628	1,000
Induced polarization	.7	[150]	10,000	[200]	13,333	[66]
Induced polarization	(25.5)	458	97,500	(17)	(3,823)	212
Radiometric						
Gamma ray	6.2	133	84,134	21	13,461	632
Gamma ray	(25.0)	516	23,800	(20)	(952)	46
Neutron activation	.2	10	7,800	40	31,200	780
Neutron activation	1.5	[150]	12,000	[100]	8,000	[80]
Remote sensing						
Multispectral scanning	2.5	[405]	46,490	[162]	18,596	[114]
Magnetotelluric	3.5	33	164,000	9	46,857	4,969
Magnetotelluric	(5.0)	[100]	327,000	[20]	(65,400)	[3,270]
Other	16.1	677	304,885	41	18,866	450
Marine						
Seismic (*P*-wave)						
Compressed air	2.3	770	1,570,000	334	682,608	2,038
Airborne						
Magnetic	73.3	497,970	7,851,144	6,787	107,007	15
Magnetic	(23.6)	73,570	1,230,800	(3,117)	(52,152)	16
Electromagnetic						
Time domain	2.0	12,139	839,016	6,069	419,508	69
Frequency domain	2.0	3,328	489,582	1,664	244,791	147
Combined EM/Mag.	23.4	36,500	3,608,000	1,559	154,188	98
VLF	(8.0)	251	40,000	(31)	(5,000)	159
Input	35.5	79,628	5,650,691	2,243	159,174	70
Radiometric						
Gamma ray	2.8	21,448	536,200	7,632	190,818	25
Gamma ray	(50.0)	58,437	334,050	(1,168)	(6,681)	5

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs - US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Minerals, Airborne (cont.)						
Remote sensing						
Multispectral scanning	(7.0)	23,125	277,500	(3,303)	(39,642)	12
Other	6.1	26,373	1,102,116	4,323	180,674	41
Drill hole						
Magnetic	(2.0)	(15,000)	12,000	(7,500)	(6,000)	(1)
Resistivity	(2.0)	(24,000)	12,000	(12,000)	(6,000)	(1)
Sonic/velocity logging	2.0	(53,000)	160,000	(26,500)	80,000	(3)
Electromagnetic						
Time domain	(2.3)	(12,000)	14,000	(5,217)	(6,086)	(1)
Frequency domain	.2	(1,500)	1,385	(6,000)	5,540	(1)
Induced polarization	4.4	(90,200)	88,436	(20,224)	19,828	(1)
Radiometric						
Gamma ray	7.5	(101,075)	59,170	(13,387)	7,837	(1)
Temperature gradient	(2.0)	(15,000)	12,000	(7,500)	(6,000)	(1)
Engineering						
Land						
Seismic (*P*-wave)						
Dynamite	3.0	67	695,324	22	231,774	10,377
Compressed air	2.0	300	690,000	150	345,000	2,300
Electrical	.3	50	60,000	166	200,000	1,200
Weight drop	7.8	73	245,600	9	31,487	3,332
Solid chemical	1.1	3	15,350	2	13,954	4,951
Vibratory	4.0	300	428,000	75	107,000	1,426
Passive monitoring	12.0	[5]	150,000	[1]	12,500	[30,000]
Other	5.0	26	70,000	5	14,000	2,692
Seismic (refraction)						
Dynamite	3.1	35	382,600	11	123,419	10,931
Dynamite	(2.6)	12	25,500	(4)	(9,807)	1,992
Dynamite	(21.0)	[210]	325,340	[10]	(15,492)	[1,549]
Compressed air	(10.0)	[1,000]	200,000	[100]	(20,000)	[200]
Weight drop	2.6	2	26,000	1	10,000	10,833
Weight drop	(.8)	1	6,796	(1)	(8,390)	4,854
Solid chemical	.5	1	18,000	1	36,000	90,900
Resistivity	47.7	1,295	593,440	27	12,441	458
Resistivity	.5	[48]	24,000	[96]	48,000	[500]
Resistivity	(4.0)	1	200	(1)	(50)	400
Resistivity	(5.0)	[975]	20,000	[195]	(4,000)	[20]
Electromagnetic						
Time domain	.1	[24]	12,000	[240]	120,000	[500]
Time domain	(2.0)	41	36,500	(20)	(18,250)	890
Remote sensing						
Thermal infrared	(1.0)	1	10,000	(1)	(10,000)	20,000
Microwave radiometry	28.0	3,000	1,500,000	107	53,571	500
Other	(3.6)	4	20,000	(1)	(5,434)	4,651
Marine						
Seismic (*P*-wave)						
Compressed air	9.0	2,154	3,200,000	239	355,555	1,485
Electrical	23.1	4,790	3,020,000	207	130,735	630
Gas exploder	9.3	1,740	2,065,000	187	222,043	1,186
Seismic (refraction)						
Dynamite	3.0	20	480,000	6	160,000	24,000
Compressed air	8.9	5,405	1,115,000	605	125,000	206
Electrical	.6	360	52,500	600	87,500	145

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Engineering, Marine (cont.)						
Magnetic	.5	100	20,000	200	40,000	200
Other	1.0	100	120,000	100	120,000	1,200
Drill Hole						
Seismic (refraction)						
Weight drop	(1.0)	(8,000)	9,000	(8,000)	(9,000)	(1)
Magnetic	(.5)	(500)	3,000	(1,000)	(6,000)	(6)
Resistivity	(.5)	(3,000)	3,000	(6,000)	(6,000)	(1)
Self-potential	(4.6)	(32,000)	26,000	(6,956)	(5,652)	(1)
Sonic/velocity logging	(5.3)	(22,000)	15,000	(4,150)	(2,830)	(1)
Radiometric						
Gamma ray	(1.5)	(9,500)	21,380	(6,333)	(14,253)	(2)
Temperature gradient	(2.3)	(2,300)	11,500	(1,000)	(5,000)	(5)
Other	(63.6)	(110,580)	559,900	(1,738)	(8,803)	(5)
Geothermal						
Land						
Seismic (*P*-wave)						
Dynamite	1.5	60	375,000	40	250,000	6,250
Seismic (refraction)						
Passive monitoring	24.0	[240]	200,000	[10]	8,333	[833]
Gravity	9.5	1,605	220,000	168	23,157	137
Gravity	4.0	[2,000]	50,000	[500]	12,500	[25]
Resistivity	8.5	255	170,000	30	20,000	666
Electromagnetic						
Time domain	.7	[123]	55,000	[175]	78,571	[447]
Temperature gradient	1.0	1,312	131,200	1,312	131,200	100
Magnetotelluric	1.0	[86]	290,879	[86]	290,879	[3,382]
Magnetotelluric	(1.0)	[28]	92,372	[28]	(92,372)	[3,299]
Groundwater						
Land						
Seismic (*P*-wave)						
Other	(4.0)	10	41,248	(2)	(10,312)	4,124
Seismic (refraction)						
Dynamite	16.0	149	294,540	9	18,408	1,970
Gravity	.5	35	8,500	70	17,000	242
Magnetic	1.0	74	15,500	71	14,903	209
Resistivity	17.5	971	116,974	55	6,684	120
Resistivity	11.0	[250]	100,000	[22]	9,090	[400]
Resistivity	(2.0)	[75]	10,840	[37]	(5,420)	[144]
Electromagnetic						
Time domain	3.0	60	60,000	20	20,000	1,000
Frequency domain	.5	5	3,000	10	6,000	600
VLF	.5	5	3,000	10	6,000	600
Other	(.6)	5	8,000	(8)	(13,333)	1,600
Marine						
Seismic (*S*-wave)						
Electrical	1.0	50	10,000	50	10,000	200
Drill Hole						
Resistivity	3.5	(14,700)	29,400	(4,200)	8,400	(2)
Resistivity	(.9)	(6,900)	7,800	(7,113)	(8,041)	(1)
Sonic/velocity logging	4.0	(45,000)	100,000	(11,250)	25,000	(2)

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Oceanography						
Marine						
Seismic (*P*-wave)						
Electrical	9.2	41,350	1,743,000	4,494	189,456	42
Implosive	9.5	11,875	1,781,250	1,250	187,500	150
Seismic (refraction)						
Compressed air	1.0	50	120,000	50	120,000	2,400
Magnetic	.6	32,100	110,000	53,500	183,333	3
Remote sensing						
Multispectral scanning	5.0	[4]	550,000	[1]	110,000	[137,500]
Other	6.0	10,000	1,800,000	1,666	300,000	180
Airborne						
Gravity	1.5	[39,000]	640,000	[26,000]	426,666	[16]
Magnetic	15.8	204,090	1,449,616	12,884	91,516	7
Drill Hole						
Radiometric						
Gamma ray	(.5)	(500)	3,000	(1,000)	(6,000)	(6)
Research						
Land						
Seismic (*P*-wave)						
Dynamite	10.9	730	2,714,807	66	249,064	3,718
Weight drop	.2	12	20,000	48	80,000	1,666
Vibratory	8.6	366	1,793,157	42	208,506	4,899
Other	1.0	2	6,000	2	6,000	3,000
Seismic (*S*-wave)						
Solid chemical	2.0	5	25,000	2	12,500	5,000
Vibratory	9.0	449	2,062,767	49	229,196	4,594
Seismic (refraction)						
Dynamite	2.0	500	57,400	250	28,700	114
Weight drop	.7	12	35,000	16	46,666	2,800
Weight drop	(3.5)	1	6,201	(1)	(1,727)	20,670
Solid chemical	1.0	5	6,000	5	6,000	1,200
Gravity	8.0	2,079	108,590	257	13,422	52
Gravity	3.0	[500]	10,000	[166]	3,333	[20]
Gravity	(9.5)	[1,732]	29,000	[182]	(3,052)	[16]
Magnetic	18.5	547	112,590	29	6,085	205
Resistivity	5.7	1,777	52,000	309	9,043	29
Self-potential	.3	1	15,000	3	50,000	15,000
Electromagnetic						
Time domain	7.0	6	35,000	1	5,000	5,833
Electromagnetic						
Frequency domain	.2	5	10,000	20	40,000	2,000
Frequency domain	(1.0)	[40]	25,000	[40]	(25,000)	[625]
Induced polarization	10.0	64	400,000	6	40,000	6,250
Magnetotelluric	9.0	380	385,280	42	42,808	1,013
Magnetotelluric	4.0	[212]	150,000	[53]	37,500	[707]
Other	(5.0)	[160]	17,000	[32]	(3,400)	[106]
Marine						
Seismic (*P*-wave)						
Compressed air	4.3	12,819	1,251,352	2,981	291,012	97
Electrical	(1.2)	1,010	202,000	(808)	(161,600)	200
Seismic (refraction)						
Compressed air	.5	576	500,000	1,152	1,000,000	868
Magnetic	5.5	13,674	410,750	2,486	74,681	30

*Total includes government and university activity.

Table 17. Worldwide average unit costs by survey objective, type, and method (cont.).

Area, survey type, and method	Total* crew-months or (man-months)	Miles or (footage) or [stations]	Acquisition costs – US$	Average miles or (footage) or [stations]/ crew-month or (man-month)	Average cost/ crew-month or (man-month)	Average cost/ mile or (foot) or [station]
Research (cont.)						
Airborne						
Magnetic	19.4	167,705	1,750,000	8,622	89,974	10
Magnetic	(3.0)	1,164	15,000	(388)	(5,000)	12
Electromagnetic						
Time domain	.5	200	60,000	400	120,000	300
Radiometric						
Gamma ray	.3	2,000	50,000	6,666	166,666	25
Remote sensing						
Thermal infrared	(9.0)	13,422	443,000	(1,491)	(49,222)	33
Multispectral scanning	(12.5)	[76]	474,108	[6]	(37,928)	[6,238]
Drill Hole						
Resistivity	.2	(1,000)	5,000	(4,000)	20,000	(5)
Self-potential	.2	(1,000)	5,000	(4,000)	20,000	(5)
Self-potential	(2.0)	(24,000)	12,000	(12,000)	(6,000)	(1)
Induced polarization	(2.0)	(24,000)	12,000	(12,000)	(6,000)	(1)
Radiometric						
Gamma ray	1.0	(15,000)	75,000	(15,000)	75,000	(5)
Gamma ray	(3.5)	(26,000)	22,000	(7,428)	(6,285)	(1)

*Total includes government and university activity.

(Text continued from p. 38)

work. For geographic distribution of these expenditures, refer to Table 2.

Activity reporting on new methods

The forms mailed this year contained revisions to include methods not reported separately in the past. These methods are vertical seismic profiles and 3-D seismic surveys. Activity information was also requested on surveys performed in transition zones, the area between normal marine and land surveys. Participation in reporting on these methods and survey types was insufficient to include in the tables or to comment on in the text. The committee plans to continue to monitor these areas and encourage companies to report on these methods. When the committee considers the data to be of sufficient reliability and adequate volume, we will begin to report this information in the annual geophysical activity report.

Summary

The year 1984 saw another decline in expenditures reported for the petroleum area worldwide. Nearly all geographic areas enjoyed increases in the number of marine miles of seismic collected as compared to 1983. All areas except Australia/New Zealand and the Middle East showed a decrease in the number of land miles of seismic acquired. Activity in mining and engineering decreased as well. In general the response to our survey is good. Further attempts are being made to encourage even more complete reporting. As companies and contractors become convinced that the confidential and financially sensitive data requested on the questionnaires are being properly safeguarded and protected, we believe that more complete reporting will occur.

Acknowledgments

This report was made possible through the contributions of statistical data by companies, contractors, government agencies, and universities. For many of these organizations, compilation of these data was a long and tedious task. The Geophysical Activity Committee expresses sincere appreciation to all of those individuals who were instrumental in preparing and submitting their activity questionnaires. The Committee welcomes comments and suggestions on ways to improve this report.

A special vote of thanks goes to Jerry Henry and Rhonda Parker of the SEG Business Office who handled the voluminous chores of mailing, receiving, coding, and checking the questionnaires. I would also like to thank Bob Austin and H. T. Konkler for the long hours they worked with the computer. Every member of the Geophysical Activity Committee should be congratulated on their work and advice in determining the direction of the work, updating address lists, and analyzing computer printouts for correctness. Russell Senti, past committee chairman, had the thankless task of guiding me through the maze of data and problems in my first year as chairman. It is with special appreciation that myself, the rest of the committee and the SEG give a vote of thanks to Russ who so richly deserves it.

References

Geophysical Activity in 1983: Leading Edge, Vol. 3, no. 7, p. 49-69.

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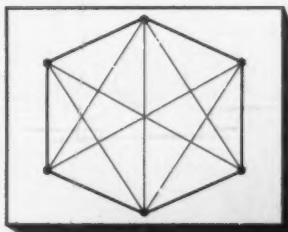

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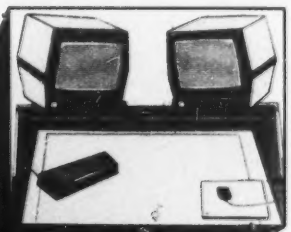

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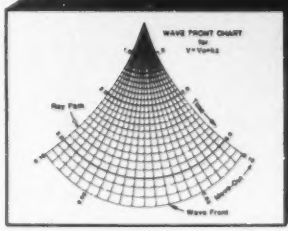

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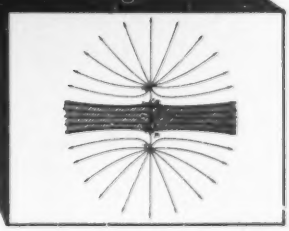

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